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(54) Method of fabricating semiconductor side wall fin

(57) A double gated silicon-on-insulator (SOI) MOSFET is fabricated by forming epitaxially grown channels, followed by a damascene gate. The double gated MOSFET features narrow channels, which increases current drive per layout width and provides low out conductance.

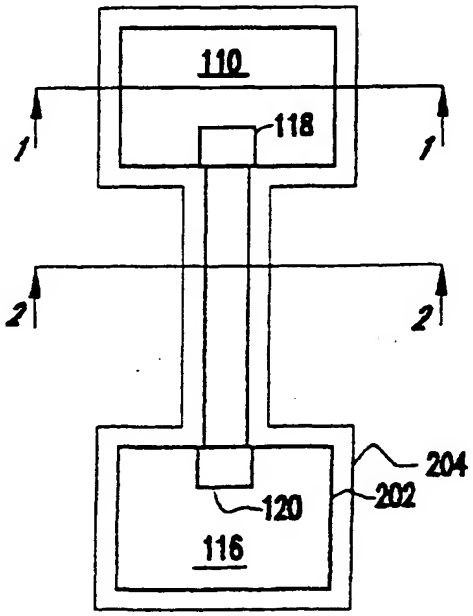

FIG.2A

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to providing a dual gate metal oxide semiconductor field effect transistor (MOSFET) transistor and, more particularly, to providing a dual gate MOSFET having relatively thin epitaxially grown channels.

BACKGROUND OF THE INVENTION

[0002] Field Effect Transistor (FET) structures may include a single gate (a single channel) or a pair of gates, with double-gate versions providing the advantage of enabling shorter channels and thus a faster device to be produced. As gate lengths scale below 50 nm, FET scaling becomes limited by the finite depth of the gate control. Research has shown that placing gates on multiple sides of an FET channel results in improved FET performance in regard to short channel characteristics and off-current characteristics. Placing gates on multiple sides of an FET channel, provided the silicon is thin enough to be fully depleted, confines electric fields and charges much more tightly than in the standard FET in which the fields are free to penetrate deeply into an effectively infinite silicon substrate. The confinement possible with a fully depleted dual gate structure allows improved short channel effects and devices having gate lengths of 20 - 30 nm are possible. The inversion induced channels will be formed on both sides of the silicon and possibly across the entire channel which may increase saturation current. Other reported benefits include nearly ideal subthreshold slope, increased saturation current and reduced short-channel and floating body effects. Requirements generally are for a thin diffusion region in the range of 5-50 nm, and gate lengths down to 20-100 nm, with the gate length preferably being two to four times the diffusion length.

[0003] A number of horizontal double-gate FET structures, and particularly SOI double-gate FET structures, have been proposed. These structures typically require a bottom gate formed beneath the thin silicon body in addition to a conventional top gate. The fabrication of such structures is difficult because the top and bottom gates must be aligned to a tolerance beyond the accuracy of state of the art lithographical equipment and methods, and because self-aligning techniques are frustrated by the layers between the top and bottom gates.

[0004] In *"Self-Aligned (Top and Bottom) Double-Gate MOSFET With a 25 nm Thick Silicon Channel"*, by Hon Sum Philip et al., IEDM 97-427, IEEE 1997, a double-gated MOSFET is considered the most promising candidate for a Complementary Metal Oxide Semiconductor (CMOS) scaled to the ultimate limit of 20-30 nm gate length. Rigorous Monte Carlo device simulations and analytical calculations predicted continual improvement in device performance down to 20-30 nm gate length, provided the silicon channel thickness can be reduced to 10-25 nm and the gate oxide thickness is reduced to 2-3 nm. However, the alignment of the top and the bottom is crucial to high performance because a misalignment will cause extra gate to source/drain overlap capacitance as well as loss of current drive.

[0005] U.S. Patent 5,780,327, by Chu et al. and entitled *"Vertical Double-Gate Field Effect Transistor"* describes a vertical double-gate field effect transistor, which includes an epitaxial channel layer and a drain layer arranged in a stack on a bulk or SOI substrate. The gate oxide is thermally grown on the sides of the stack using differential oxidation rates to minimize input capacitance problems. The gate wraps around one end of the stack, while contacts are formed on a second end. An etch-stop layer embedded in the second end of the stack enables contact to be made directly to the channel layer.

[0006] U.S. Patent No. 5,773,331 by Solomon et al. and entitled *"Method for Making Single and Double Gate Field Effect Transistors With Sidewall Source-Drain Contacts"* describes a method for making single-gate and double-gate field effect transistors having a sidewall drain contact. The channel of the FETs is raised with respect to the support structure underneath and the source and drain regions form an integral part of the channel.

[0007] U.S. Patent No. 5,757,038 by Tiwari et al. and entitled *"Self-Aligned Dual Gate MOSFET with an Ultra-narrow Channel"* is directed to a self-aligned dual gate FET with an ultra thin channel of substantially uniform width formed by a self-aligned process. Selective etching or controlled oxidation is utilized between different materials to form a vertical channel extending between source and drain regions, having a thickness in the range from 2.5 nm to 100 nm.

[0008] U.S. Patent No. 5,580,802 to Mayer et. al. and entitled *"Silicon-on-Insulator Gate-All-Around MOSFET Fabrication Methods"* describes an SOI gate-all-around (GAA) MOSFET which includes a source, channel and drain surrounded by a top gate, the latter of which also has application for other buried structures and is formed on a bottom gate dielectric which is formed on source, channel and drain semiconductor layers of an SOI wafer.

[0009] U.S. Patent No. 5,308,999 to Gotou and entitled "MOS FET Having a Thin Film SOI Structure" describes a MOS FET having a thin film SOI structure in which the breakdown voltage of an MIS (Metal Insulator Semiconductor) FET having an SOI structure is improved by forming the gate electrode on the top surface and two side surfaces of a channel region of the SOI layer and by partially extending the gate electrode toward the inside under the bottom of the channel region such that the gate electrode is not completely connected.

[0010] U.S. Patent No. 5,689,127 to Chu et al. and

entitled *"Vertical Double-Gate Field Effect Transistor"* describes a vertical double-gate FET that includes a source layer, an epitaxial channel layer and a drain layer arranged in a stack on a bulk or SOI substrate. The gate oxide is thermally grown on the sides of the stack using differential oxidation rates to minimize input capacitance problems. The gate wraps around one end of the stack, while contacts are formed on a second end. An etch-stop layer embedded in the second end of the stack enables contact to be made directly to the channel layer.

[0011] The lithographically defined gate is by far the simplest, but suffers from a number of disadvantages. First, definition of the gate may leave poly spacers on the side of the diffusions or may drive a required slope on the side of the diffusion, thereby resulting in a poorer quality and/or more poorly controlled device. Second, the slope of the poly inherently leads to difficulty in forming silicided gates, leading to slower device performance. Finally, the poly step height poses a difficult problem for lithographic definition, as we expect steps on the order of 100 nm - 200 nm in a 50 nm design rule technology.

[0012] The key difficulties in fabricating double-gated FETs are achieving silicidation of thin diffusions or polysilicon with acceptable contact resistance, enabling fabrication of the wraparound gate without misalignment of the two gates, and fabrication of the narrow diffusions (ideally, 2-4 times smaller than the gate length).

[0013] Additional techniques for generating the dual-gated transistors include defining the gate lithographically with high step heights (see U.S. Patent No. 4,996,574 to Shirasaki, entitled *"MIS Transistor Structure for Increasing Conductance Between Source and Drain Regions"*), forming a selective epitaxial growth which provides an "air-bridge" silicon structure (see Hon-Sum Philip Wong, International Electron Devices Meeting (IEDM) 1997, pg .427), and forming wrap-around gates with vertical carrier transport (see H. Takato IEDM, 1988, pg. 222).

[0014] In summary, previous fabrication schemes have relied upon litographically defined silicon channels and long, confined lateral epitaxial growth. However, a lithographically defined channel cannot be formed with sufficiently close tolerances and even avalable tolerances cannot be maintained adequately to support near-optimal dual gate transistor performance in the above approaches. Further, techniques using lateral current flow with FET widths defined laterally suffer from difficulty in aligning the top and bottom gates even though thickness of silicon can be tightly controlled.

[0015] U. S. Patent application 09/526,857, by James W. Adkisson, John A. Bracchitta, John J. Ellis-Monaghan, Jerome B. Lasky, Kirk D. Peterson and Jed H Rankin, filed on March 16, 2000, entitled "Double Planar Gated SOI MOSFET Structure" describes a method to create the double gate transistor, assuming the channel width can be made small enough.

DISCLOSURE OF THE INVENTION

[0016] It is an advantage of the present invention to provide a dual gate transistor having relatively thin epitaxially grown channels.

[0017] According to the invention, there is provided a method of forming a field effect transistor (FET) transistor, comprising the steps of forming silicon layers on a substrate. Next, epitaxial channels are formed on a side surface of the silicon layers, with one side wall of the channels therefore being exposed. The silicon layers are then removed, thereby exposing a second sidewall of the epitaxial channels. Source and drain regions are then formed, coupled to ends of the epitaxial channels. Finally, a gate is formed over the epitaxial channels.

[0018] The invention thus seeks to provide a very thin diffusion region using a known technique for growing epitaxial regions to form the very thin channel and has the advantages of providing much tighter tolerances on channel thickness than a lithographically defined channel which can be maintained by selective etching and that epitaxial growth is not complicated by thee presence of thin confining layers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The present invention will now be described, by way of example only, with reference to preferred embodiments thereof, as illustrated in the following drawings, in which:

Figure 1A is top view of the device showing a silicon line;

Figure 1B is a cross sectional view of cut 1-1 shown in Figure 1A;

Figure 1C is a cross sectional view of cut 2-2 shown in Figure 1A;

Figure 2A shows the substrate of Figure 1A after epitaxial growth of etch stop and channel layers;

Figure 2B is a cross sectional view of cut 1-1 shown in Figure 2A;

Figure 2C is a cross sectional view of cut 2-2 shown in Figure 2A;

Figure 3A shows Figure 2A with a mask opening for silicon line removal;

Figure 3B shows a cross sectional view of cut 2-2 shown in Figure 3A;

Figure 4A shows Figure 3A after the removal of any remaining portion of the silicon line and the etch stop layer;

Figure 4B shows a cross sectional view of the 2-2 cut shown in Figure 4A;

Figure 5 shows the device of Figure 4A after the formation of a second channel;

Figure 6 is a representational cross section of cut 2-2 shown in Figure 5;

Figure 7 shows the substrate of Figure 6 after shallow trench isolation (STI) fill and polish;

Figure 8A is a representational cross section of cut 2-2 shown in Figure 11B, after a polysilicon conductor (PC) resist mask is applied and etching;

Figure 8B is a representational cross section of cut 2-2 shown in Figure 11B, after a PC resist mask is applied;

Figure 9A shows the substrate of Figure 8A after gate dielectric growth or deposition, and gate conductor deposition;

Figure 9B shows the substrate of Figure 8B after removal of the PC resist mask;

Figure 10A shows removal of STI and isolation implants in the substrate of Figure 9A;

Figure 10B shows extension implants in the substrate of Figure 9B;

Figure 11A shows the completed device of Figure 10A before contacts;

Figure 11B shows a top view of the completed device, and

Figure 12 illustrates a technique of removing defective material due to excessive faceting.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0020] Referring now to Figure 1A, there is shown a top view of a starting silicon-on-insulator (SOI) substrate 100. As shown in Figures 1B and 1C, which correspond to sections 1-1 and 2-2 shown in Figure 1A, respectively, the substrate 100 is comprised of a bulk substrate 106, a buried oxide (BOX) 108 layer, and an active layer 110. Figures 1B and 1C also show an oxide pad film 102 and a nitride pad film 104 on active layer 110. Those skilled in the art will realize that it may be preferable to have the oxide pad film 102 placed on top of the nitride pad film 104. The pad oxide 102 is grown using standard oxidation techniques and would typically be in the range of 3 to 14 nm, with 8 nm being preferred. Pad films 104 are placed upon pad oxide 102. It is preferred that nitride films be utilized as pad films 104, although other materials may also be used. The nitride (upper) pad films 104 are typically in the range of 30 to 120 nm, with 80 nm being preferred, and define the etch areas for shallow trench isolation (STI) formation.

[0021] The active device layer 110 is patterned to form edges 112 where the silicon channel will be formed. The width 113 of active layer 110, which is used to form what will become the channel region, is not critical, other than it must be wide enough for masking and narrow enough to confine overetching, thereby providing an adequate, practical manufacturing tolerance. It is preferred that the silicon regions that will become the source 114 and drain 116 areas and contact areas 118, 120 be formed during this stage in accordance with conventional processing techniques known to those skilled in the art.

[0022] Figures 2A, 2B and 2C correspond to Figures 1A, 1B and 1C, respectively, after epitaxial growth of etch stop 202 and subsequent epitaxial growth of the channel 204. Preferably, the etch stop is comprised of Si(0.3)Ge (0.7), and that the epitaxially grown channel be comprised of silicon or alloys of silicon with germanium and/or carbon. Alloys of silicon with other Group IV elements (particularly germanium and carbon) can be used to optimize the FET performance by adding strain to the channel and/or modifying the conduction and valence bands across the channel to alter the device threshold or improve carrier transport. It will be evident to those skilled in the art that, prior to formation of etch stop 202 and channel 204, a suitable cleaning process is used to remove a portion of the silicon 110 under the oxide pad film 104. The width of the removed silicon should be approximately equal to the combined width of the etch stop 202 and channel 204.

[0023] Non-selective epitaxial deposition of etch stop 202 and channel 204 may be required if faceting is excessive, although selective deposition is preferred. Preferably, the thickness of layer 202 is approximately 5 nm. Faceting will be highly dependent on details of epitaxial growth. Particularly with selective epitaxial growth, faceting may alter the thickness of the epitaxial regions as the edge of the opening is approached. Since the channel is projected to be very thin relative to the height of the growth, the area where the channel will be impacted is likely to be small. The allowed thickness before dislocations are created is sensitive to the Ge fraction and decreases quickly with increase in the Ge fraction (see A. Fischer and H. Kuhne, "Critical Dose for Strained Layer Configurations", Phys. Stat. Sol. (a), 155, 141, 1996). Then, channel 204 is epitaxially grown, preferably in the range 5-50 nm.

[0024] The bottom and top of channel 204 may be defective. Particularly if the epitaxial layer is thin, the region is likely to be extremely small and may not be significant to the formation of the device. However, if it is necessary to reove these regions, two processes are available to do so at small but tolerable, degrade of de-

vice width control. Specifically, a spacer could be deposited similar to that of spacer 302 of Figure 3B, but etched lower to uncover the top of the epitaxial region. After this spacer is formed, the buried oxide is etched underneath the spacer as shown on the left side of Figure 12. Alternatively, a thin composite spacer may be used. In this case, the bottom of the spacer are isotropically etched to uncover the top and bottom regions. The height of the spacer (overetch) is determined by the undercut necessary to reach the epitaxial region at the bottom of the spacer, as shown on the right side of Figure 12. After the defective regions are etched, the spacers are removed selectively to the epitaxial regions and the buried oxide layer before proceeding to following processing steps. It should be noted that it is also possible to perform the procedure described above after the spacer shown in Figure 4B is removed with the spacers of the above described procedure being removed before further processing.

[0025] Figures 3A and 3B correspond to Figures 2A and 2C, respectively, after additional processing steps, as described below. As shown in Figure 3B, spacers 302 are formed, using a suitable technique and material widely known to those skilled in the art, to protect the channel 204 against attack.

[0026] Then, a mask is applied and positioned such that the mask opening 304, shown in Figure 3A, provides for removal of the exposed portion of silicon layer 110 and etch stop 202 within the mask opening 304. It is preferred that the mask 304 be aligned as closely as possible to the channel 204. The exposedd silicon 110 within mask opening 304 is then etched using an anisotropic etch.

[0027] The exposed silicon 110 within mask opening 304 is then etched. Since not all of the silicon 110 will be removed during this etch, the silicon layer 110 is also etched laterally, stopping on etch stop 202 (see K.D. Hobart, F.J. Kub, M.E. Twigg, G.G. Jernigan, P.E. Thompson, "Ultra-Cut: A Simple Technique for the Fabrication of SOI Substrates with Ultra-thin (<5nm) Silicon Films", Proc. IEEE International Silicon on Insulator (SOI) Conference, p 145-146, Oct. 1988.) KOH can be utilized as an etchant, which has a selectivity of approximately 20: 1 for Si:Si(O.3)Ge(O.7), whereas NH_4OH is reported to have a selectivity of better than 100:1 for a 25% Ge film (see G. Wang et. al., "Highly Selective Chemical Etching of Si vs. Si(1 -x)G(x) using NH40H solution, J. Electrochem. Soc., Vol. 144(3), Mar 1997, L37).

[0028] Thus, with an overlay of approximately 70 nm, and an edge tolerance of approximately 20 nm, the expected thickness required is approximately 85 nm. Assuming a 20% overetch, a 100 nm etch will be required. The worst case SiGe attack would then be approximately 5 nm when KOH is utilized as the etchant, and approximately 1 nm with NH_4OH is utilized as the etchant.

[0029] Next, etch stop 202 is selectively etched to the channel 204. The selectivity for $HF:H_2O_2:CH_3COOH$ is approximately 1000:1 for a 70% Ge film. Assuming a 10 nm etch, Si attack is therefore negligible. The selectivity for $HNO_3:H_2O:HF$ (40:20:5) is approximately 25:1 selectivity for a 50% Ge film. The effective HF dilution is approximately 12:1. Oxide attack will be significant, but can be controlled in accordance with conventional processing steps widely known to those skilled in the art. Etch rates for $HNO_3:H_2O:HF$ are approximately 40 nm/min, suggesting very short exposures, and probably allowing further dilution for control. (see D.J. Godbey et. al., "Selective Removal of Si(1 -x)Ge(x) from <100> Si using HNO_3 and HF, J. Electrochem. Soc., 139(10), 2943, 1992). Spacers 302 can be removed, if necessary. in accordance with conventional processing steps widely known to those skilled in the art.

[0030] Figures 4A and 4B correspond to Figures 3A and 3B, respectively, after the etching of active layer 10 and etch stop 202. If necessary, a trim mask can be applied to remove undesired fins 402 in accordance with conventional processing techniques widely known to those skilled in the art. Figure 5 shows the device of Figure 4A after the formation of a second channel 502 which, as will be readily recognized by those skilled in the art, can be formed by using the same processing steps as previously described to for the first channel 204.

[0031] Having formed the first 204 and second 502 channel regions, a first sequence of final processing steps required to complete the dual-gated transistor is described below.

[0032] Referring now to Figure 6, channels 204 and 502 of Figure 5 are shown, as well as an additional channel 602 that may be used to form another gate structure. It should thus be understood by those skilled in the art that substrate 100 may comprise many channels in addition to shown channels 204, 502 and 602. Here, the substrate 100 thus comprises bulk substrate 102, BOX layer 104, and channels 204, 502 and 602.

[0033] Then, in Figure 7, a standard STI fill 702 is provided, which is preferably a silicon dioxide layer of approximately 300 to 500 nm thick. However, other suitable materials known to those skilled in the art may also be used as a sacrificial film. Preferably, the STI surface is planarized by polishing.

[0034] Figure 8A is a representational cross-sectional cut of section 1-1 of Figure 11B. Figure 8A is representational because polysilicon conductor (PC) resist 802 and STI fill 702 are present during fabrication in Figure 8A, but are not present in corresponding region 141 of Figure 11B. After placing the PC resist mask 802 on a selected regions of STI fill 702, STI fill 702 is selectively etched relative to pad films 104 and down to the BOX layer 108. It is preferred, but not required, that the etch also be selective relative to the BOX layer 108. Pad films 104 are then removed selectively to the STI fill layer 702 and BOX layer 104. Figures 9A and 10A show that the pad layers 104 could be left, if desired, to allow a thin gate dielectric 904 only on the sidewalls of channels 204, 502 and 602. It is preferred that there be approxi-

mately a 10:1 selectivity in each etch, which can be accomplished with known state of the art etches. If desired, well implants may optionally be introduced at this point. These implants would be done using highly angled implants, preferably in the range of 10 to 45 degrees, with each implant rotated at approximately 90 degrees relative to each other in order to fully dope the sidewalls of the diffusion. In order to avoid doping the surface layer of the diffusions more heavily than the sides, the implantation could be done before removing the pad films 104 in the exposed areas of PC resist 802.

[0035] Figure 8B is a representational cross-sectional cut of section 2-2 shown in Figure 11B. Figure 8B is representational because PC resist mask 802 and STI fill 702 are present during fabrication in Figure 8B, but are not shown in the region between the source 114, drain 116, and gate 902 in Figure 11B. Figure 8B thus shows the selective placement of PC mask 802 during fabrication. This can be accomplished using standard pattern lithography techniques using a PC mask preferably composed of either photoresist or a hardmask.

[0036] Figure 9A shows the substrate of Figure 8A after gate dielectric growth 904 (e.g., SiO_2), and gate conductor 902 deposition. It should be understood that nitrided oxides, nitride/oxide composites, metal oxides (e.g., Al_2O_3, $ZrSiO_4$, TiO_2, Ta_2O_5, ZrO_2, etc.), perovskites (e.g., (Ba, Sr)TiO_3, La_2O_3) and combinations of the above can also be used as the dielectric. Gate dielectric growth on each channel 204, 502 and 602 could be standard furnace or single-wafer chamber oxidations in accordance with conventional methods. If desired, nitriding species (e.g., N_2O, NO or N_2 implantation) can be introduced prior to, during, or subsequent to oxidation. Gate dielectric deposition on each channel 204, 502 and 602 can be can be accomplished, for example, through chemical vapor deposition (CVD) or other techniques known to those skilled in the art.

[0037] After etching, the gate 902 is deposited. Gate conductor deposition could be accomplished using conventional CVD or directional sputtering techniques. It should be understood that gate conductors other than polysilicon can also be used. For example, an SiGe mixture, refractory metals (e.g., W), metals (e.g., Ir, Al, Ru, Pt), and TiN can be used. In general, any material that can be polished and that has a high conductivity and reasonable workfunction can be used in place of polysilicon. After deposition, the gate 902 is polished in accordance with conventional techniques.

[0038] Figure 9B shows Figure 8B after removal of the PC resist mask 802. The STI surface 904 is cleaned in accordance with conventional techniques.

[0039] Figures 10A and 10B show extension implants to form the MOSFET device of Figure 9A after removal of STI fill 702. Implantations are done at a large angle, preferably in the range of 7 to 45 degrees, relative to a vector perpendicular to the wafer surface. Four implants, each rotated at approximately 90 degrees relative to each other about the wafer surface normal vector in order to fully dope the sidewalls of the diffusions uniformly. The pad oxide layer 102 on top of the diffusions may be utilized to avoid doping the surface of the diffusions too strongly. In this case, the pad films 104 would be removed after the implantation, but before the final implantations are done, which would follow the spacer 146 deposition.

[0040] Figure 11A shows the device of Figure 10A after formation of silicide layer 1102 in accordance with conventional steps. Also in accordance with conventional steps, after the gate 902 is formed, spacers 1104 are formed and the diffusions are annealed, and a layer of highly conformal dielectric fill 1106 is deposited, and then polished to the top of the gate conductor. It is preferred that dielectric fill 1106 is a nitride layer followed by a doped glass. Because of the high aspect ratios, fill properties suggest a rapid-thermal CVD or a self-sputtering deposition using a high-density plasma-enhanced CVD technique. Typically, the dielectric glass includes phosphorus and/or boron, but it can also be undoped.

[0041] Figure 11B shows a top view of the completed device. The source 114 and drain 116 region are formed by implantation. Contacts 1106, 1108, 1110 are added and back end of line (BEOL) processing is done in accordance with conventional steps.

[0042] Referring again to Figure 8A, the second sequence comprises the steps of removing the pad oxide 102 and pad nitride 104 films. If necessary, disposable spacers can be formed and the top of the channels 204, 502 and 602, if defective, can be etched. As shown in Figure 9A, gate oxide is then grown, and the gate 902 is deposited, preferably from among the same materials described above, and etched to form gates.

Claims

1. A field effect transistor (FET) comprising:

   a substrate;

   a source region and a drain region in the substrate, each of said source region and said drain region having a top, bottom and at least two side diffusion surfaces, the source and drain regions separated by an epitaxially grown channel region having a top, bottom and side channel surfaces substantially coplanar with corresponding ones of the diffusion surfaces;

   a gate adjacent the top and the side channel surfaces and electrically insulated from the top and side channel surfaces; and

   the gate comprising a planar top surface, the planar top surface having a contact for receiving a gate control voltage for controlling the

FET.

2. The FET as claimed in claim 1, in which the source and drain have a contact for receiving a control voltage for controlling the FET.

3. The FET as claimed in claim 1 or claim 2, in which the gate is substantially centered between and substantially parallel to said source region and said drain region.

4. The FET as claimed in any preceding claim, further comprising a silicide layer that contacts a top surface of said gate.

5. The FET as claimed in any preceding claim, further comprising a dielectric layer that contacts a first side end and a second side end of said gate.

6. The FET as claimed in any preceding claim, further comprising a dielectric that contacts side surfaces of the channels.

7. The FET as claimed in any preceding claim, where the gate is comprised of polysilicon.

8. The FET as claimed in any preceding claim, in which the channel is approximately one fourth of a length of the FET.

9. The FET as claimed in any preceding claim, further comprising a dielectric material in the gate for electrically separating the gate into two electrically isolated portions, each having a substantially coplanar top surface and a contact pad on each respective substantially coplanar top surface.

10. The FET as claimed in any preceding claim, in which said epitaxial channel is formed of a combination of Group IV elements.

11. The FET as claimed in any of claims 1 to 9, in which said epitaxial channel is formed of an alloy of silicon and a Group IV element.

12. The FET as claimed in any of claims 1 to 9, in which said epitaxial channel is formed of an alloy of silicon and at least one of germanium and carbon.

13. A method of forming a field effect transistor (FET) transistor, comprising:

providing a substrate;

forming a layer on the substrate, the layer having a side surface;

forming an epitaxial channel on the side surface, the channel having a first sidewall;

removing the layer for exposing a second sidewall of the channel;

forming source and drain regions coupled to ends of the first channel; and

forming a gate adjacent to at least one of the sidewalls of the channel.

14. A method for forming a double gated field effect transistor (FET), comprising the steps of:

forming on a substrate a first and a second epitaxially grown channels;

etching areas within a silicon layer to form a source and a drain, wherein a side surface of the source and the drain contact opposing end surfaces of the first and second epitaxially grown channels; and

forming a gate that contacts a top surface and two side surfaces of the first and second epitaxially grown channels and a top surface of the substrate.

15. The method as claimed in claim 14, in which the forming step comprises the steps of:

forming first and second silicon lines, each end of the silicon lines contact an end of the source and the drain;

forming an etch stop layer on an exposed side surface of each of the first and second silicon lines;

epitaxially growing first and second silicon layers on each etch stop layer;

etching away the first and second silicon lines and etch stop layers;

filling areas surrounding the first and second epitaxially grown silicon layers and between the source and the drain with an oxide fill;

etching a portion of the oxide fill to form an area that defines a gate, wherein the area that defines the gate is substantially centered between and substantially parallel to the source and the drain; and

depositing a material to form a gate.

16. The method as claimed in claim 15, further compris-

ing the steps of:

etching the oxide fill between the gate the source to expose the first and second epitaxially grown silicon layers; and

etching the oxide fill between the gate and the drain to expose the first and second epitaxially grown silicon layers.

17. The method as claimed in claim 15 or claim 16, further comprising the step of forming an oxide on the first and second epitaxially grown silicon layers.

18. The method as claimed in claim 17, in which the oxide is silicon dioxide.

19. The method as claimed in any of claims 16 to 18, further comprising the steps of:

implanting a portion of the epitaxially grown silicon layers between the gate and the source; and

implanting a portion of the epitaxially grown silicon layers between the gate and the drain.

20. The method as claimed in claim 19, in which the implanting step is in the range of 10 to 45 degrees relative to a vector perpendicular to a top surface of the epitaxially grown silicon layers.

21. The method as claimed in claim 19 or claim 20, in which the implants are done in a series at approximately 90 degrees relative to each other.

22. The method as claimed in any of claims 14 to 21, further comprising the step of forming a contact on each of the gate, the source and the drain.

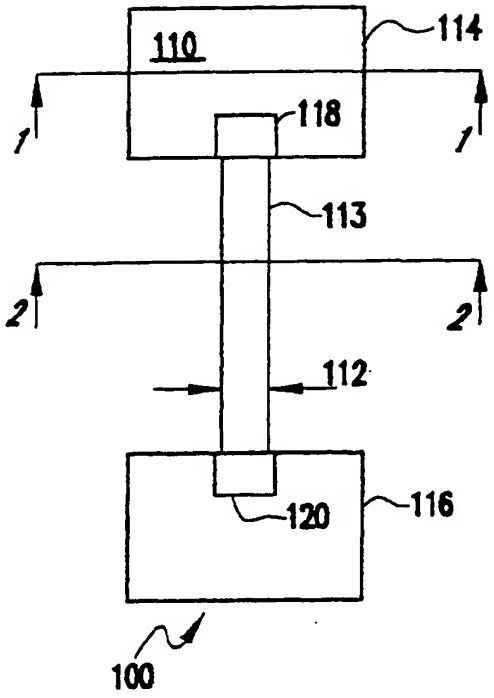

FIG.1A

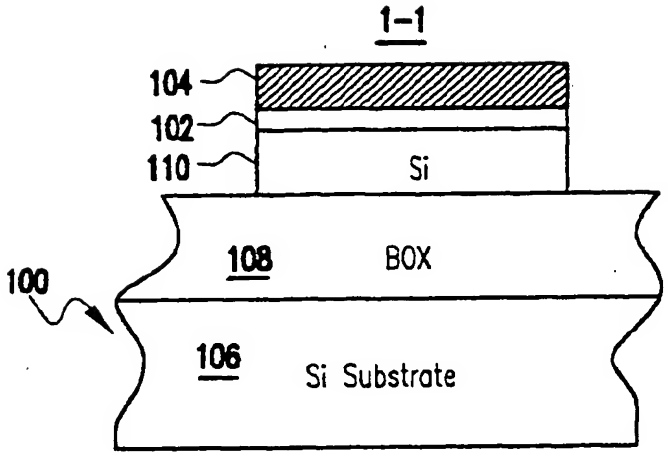

FIG.1B

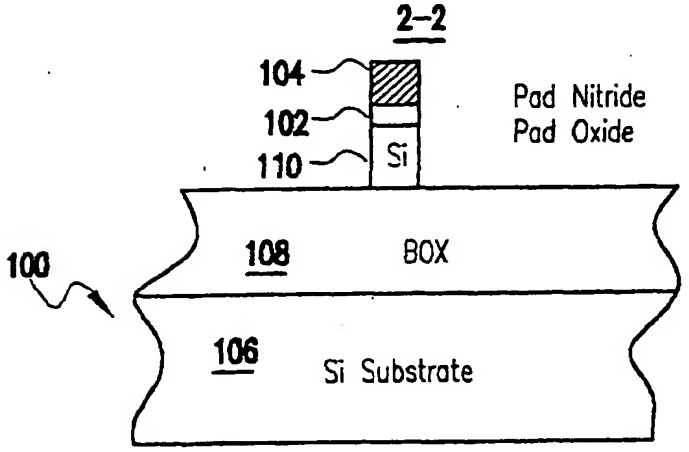

FIG.1C

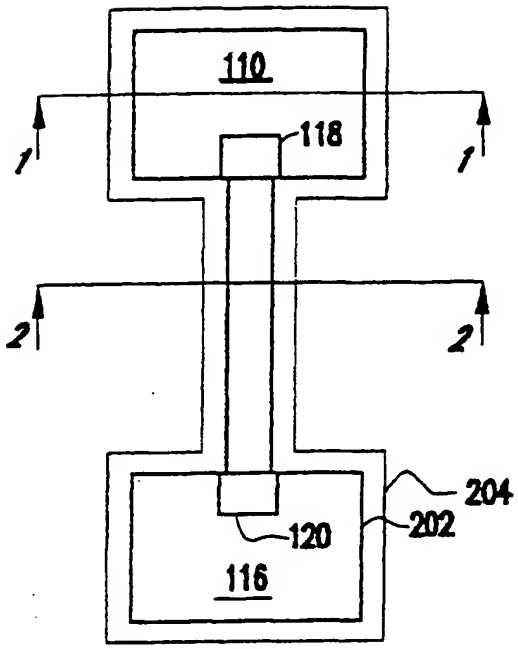

FIG.2A

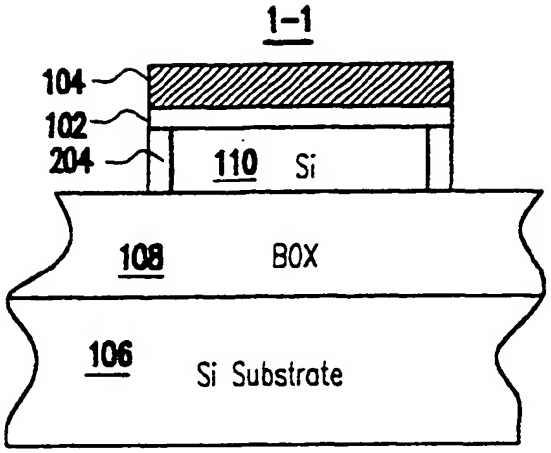

FIG.2B

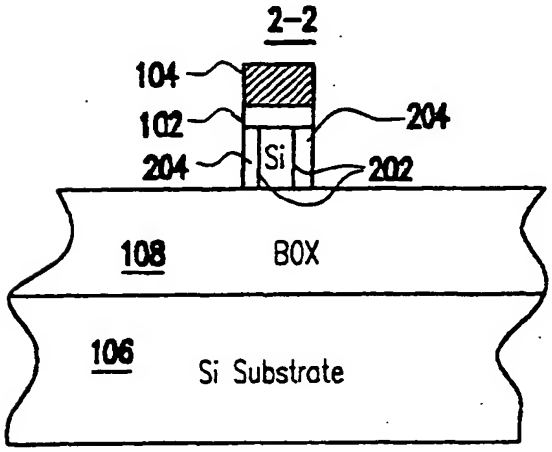

FIG.2C

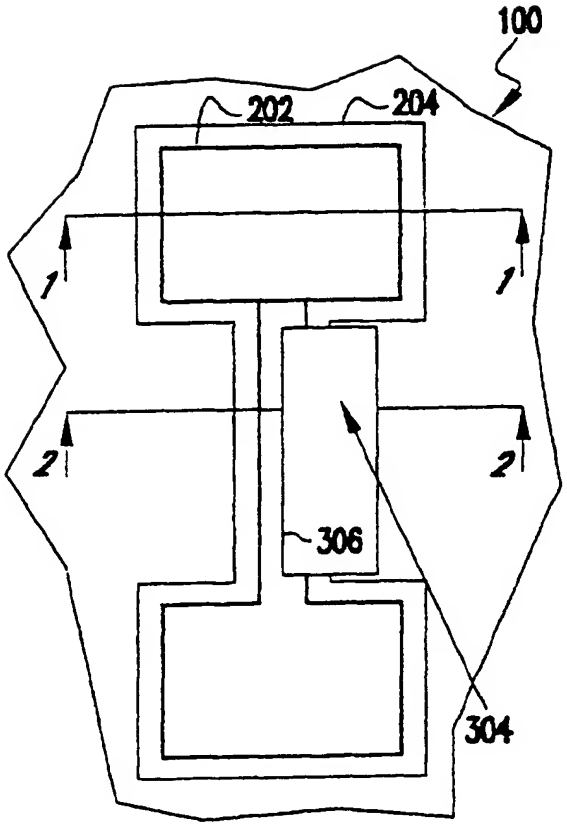

FIG.3A

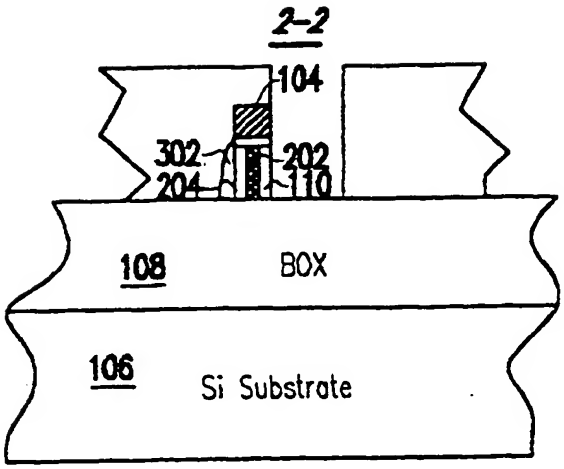

FIG.3B

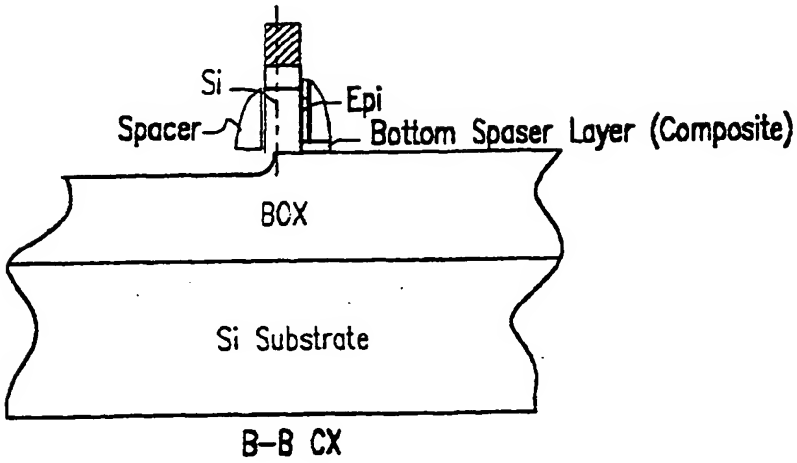

FIG.12

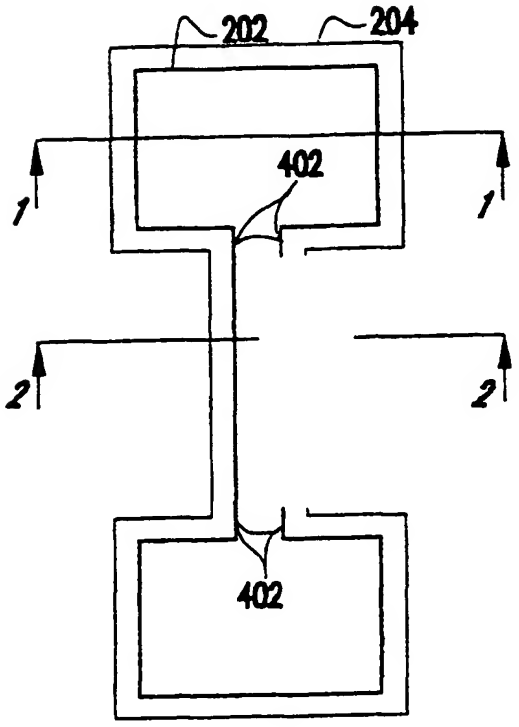
202
204
402
1
1
2
2
402

FIG.4A

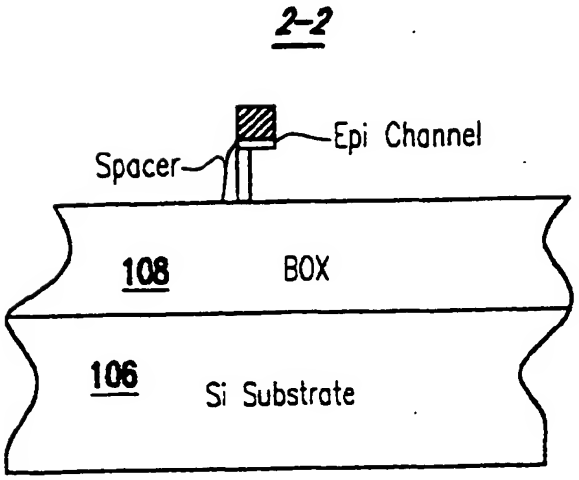
2-2
Spacer
Epi Channel
108
BOX
106
Si Substrate

FIG.4B

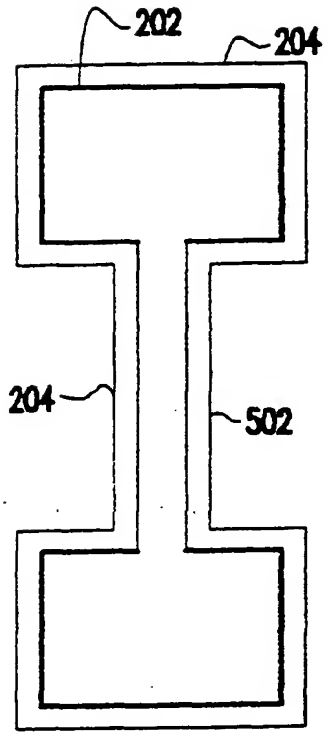

FIG.5

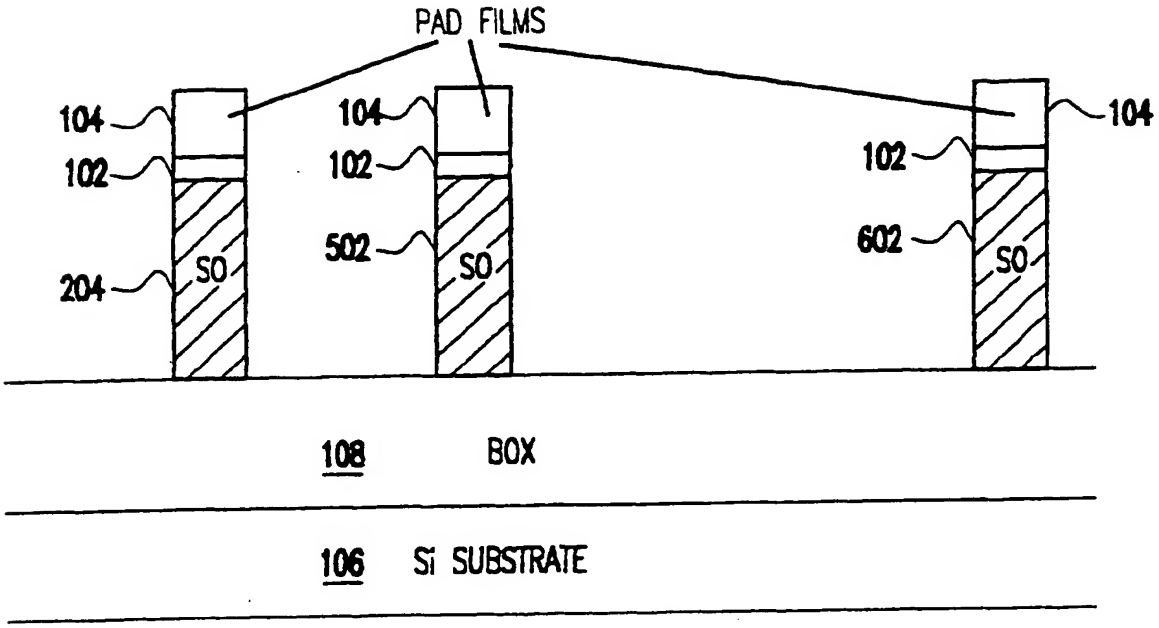
PAD FILMS
104
102
204
SO
104
102
502
SO
102
602
SO
104
108 BOX
106 Si SUBSTRATE

FIG.6

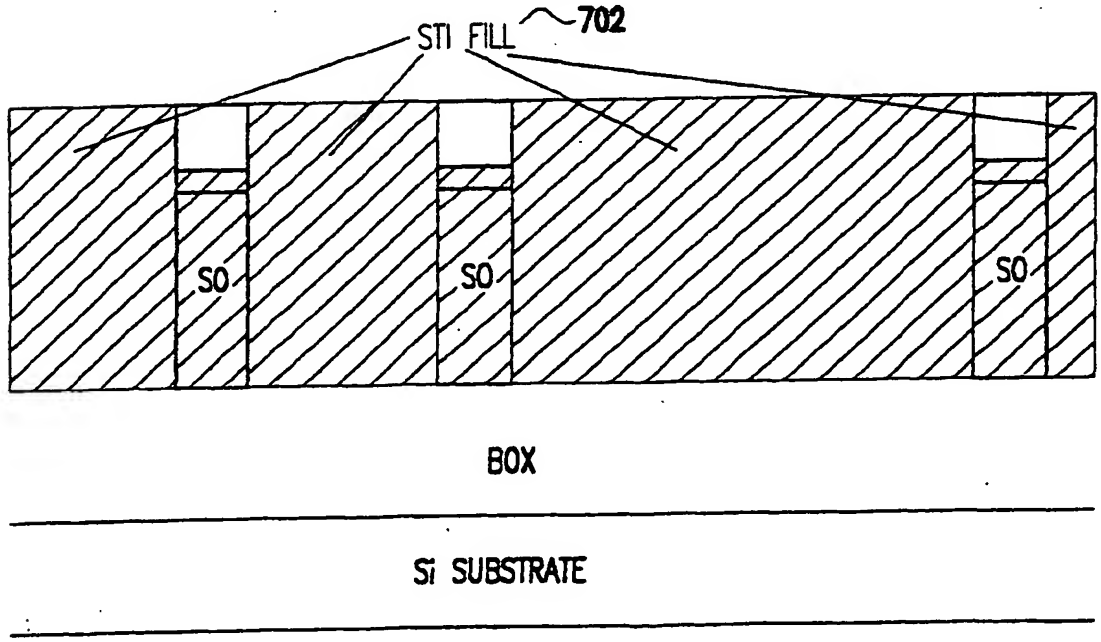
STI FILL
702
SO
SO
SO
BOX
Si SUBSTRATE

FIG.7

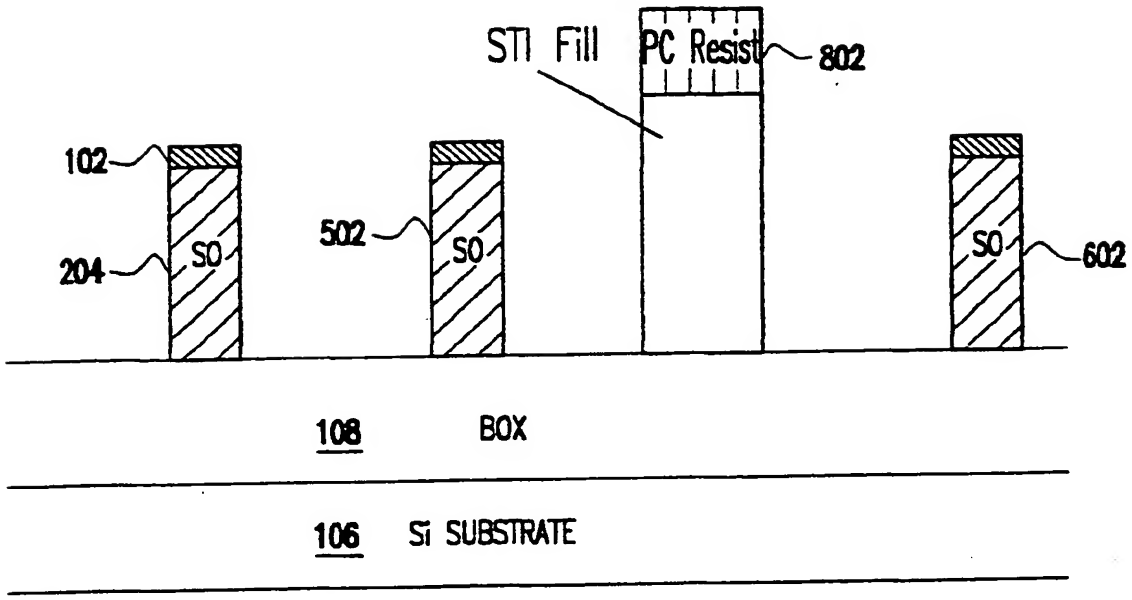
STI Fill
PC Resist
802
102
204
SO
502
SO
SO
602
108
BOX
106
Si SUBSTRATE

FIG.8A

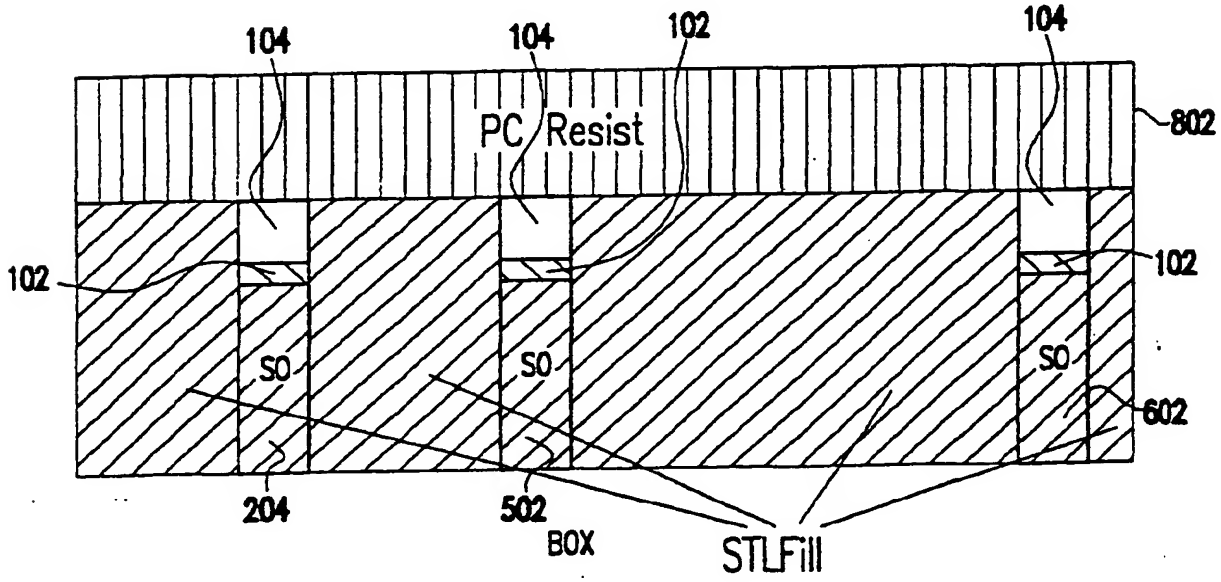
104
104
102
104
PC Resist
802
102
102
SO
SO
SO
602
204
502
BOX
STI Fill

FIG.8B

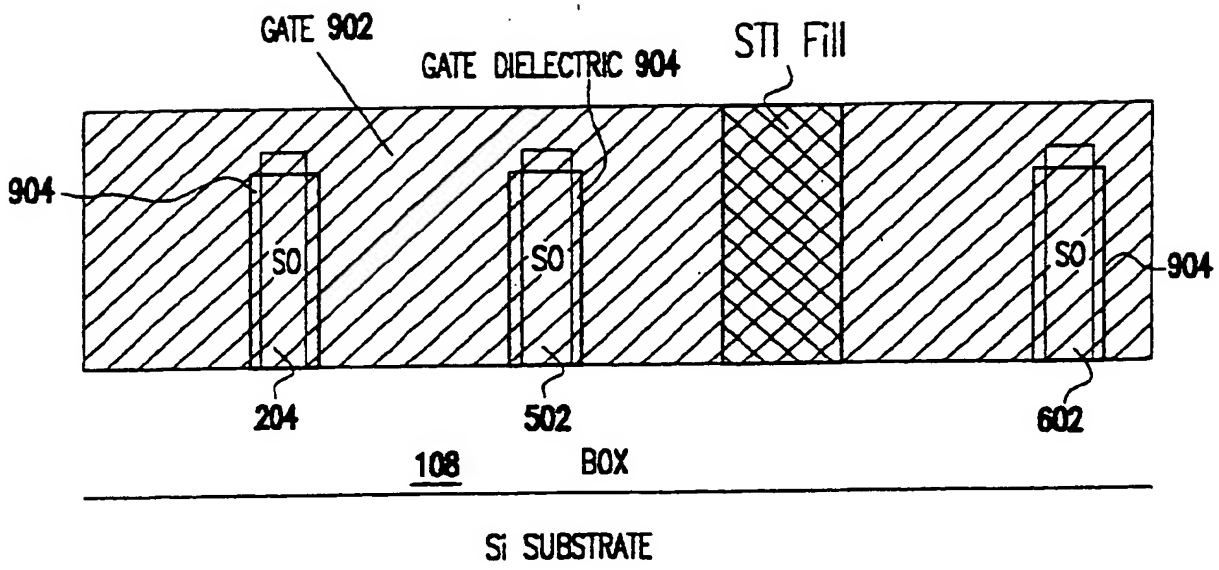
GATE 902
GATE DIELECTRIC 904
STI Fill
904
SO
SO
SO
904
204
502
602
108
BOX
Si SUBSTRATE

FIG.9A

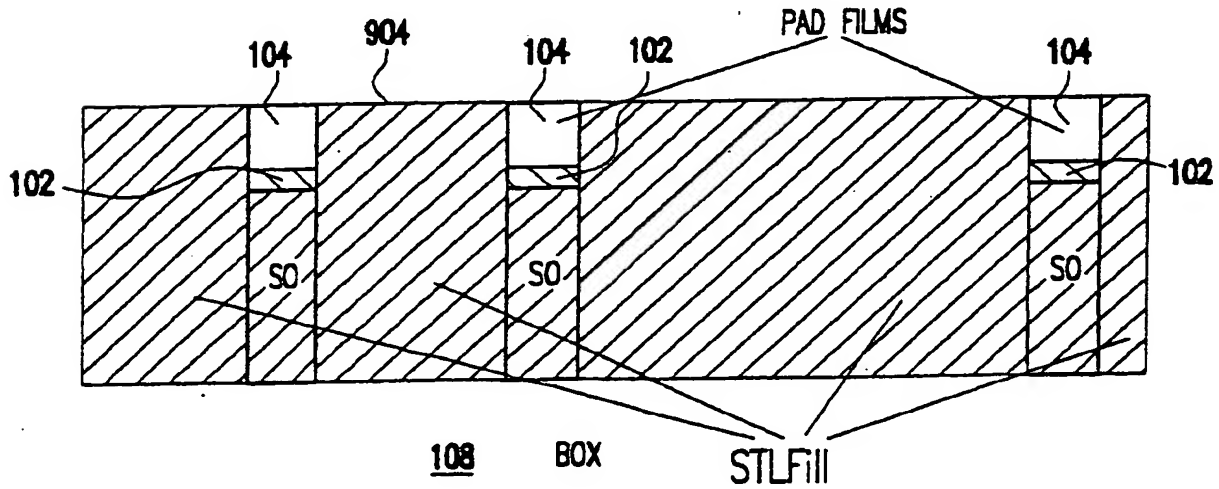
104
904
104
102
PAD FILMS
104
102
102
SO
SO
SO
108
BOX
STI Fill

FIG.9B

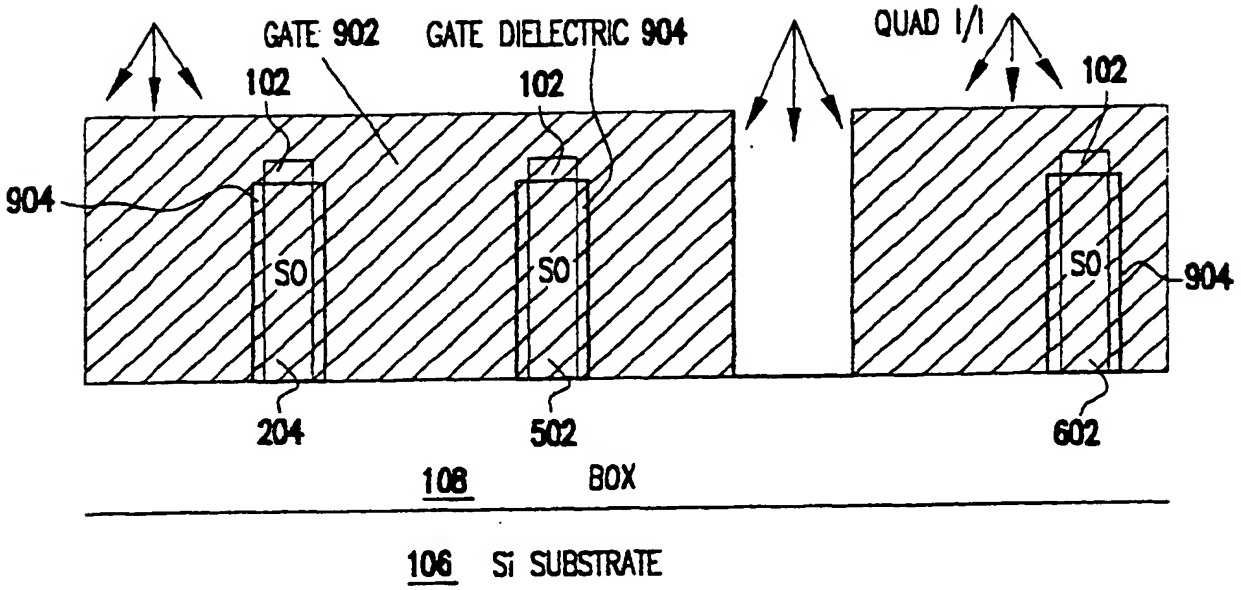

FIG.10A

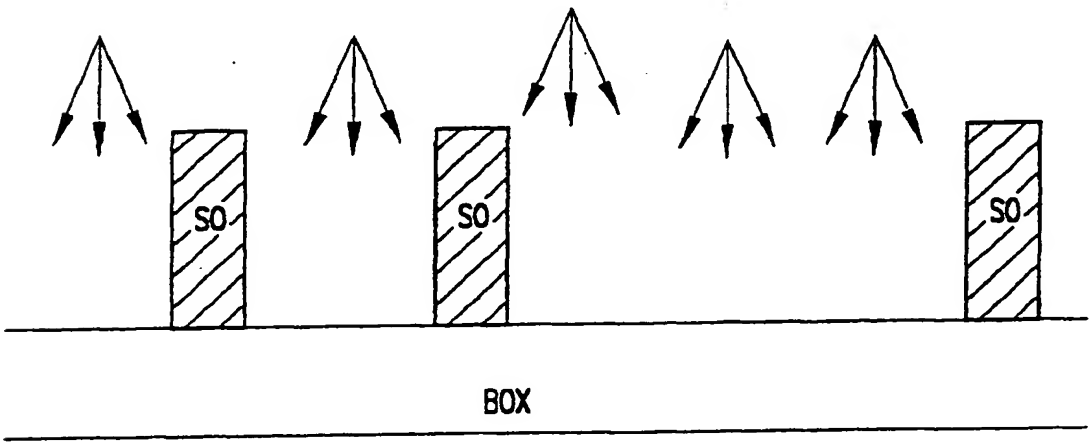

FIG.10B

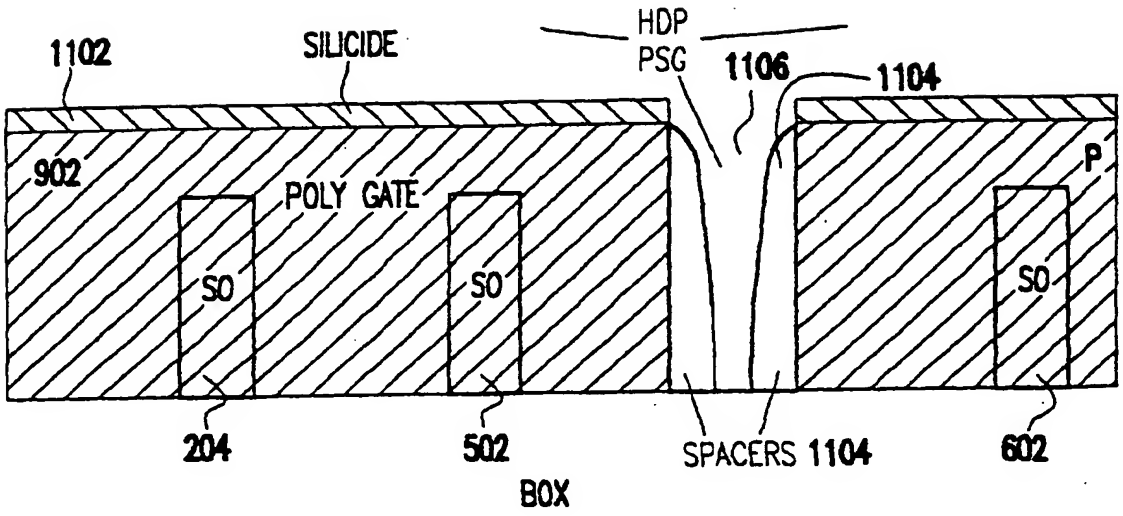

FIG.11A

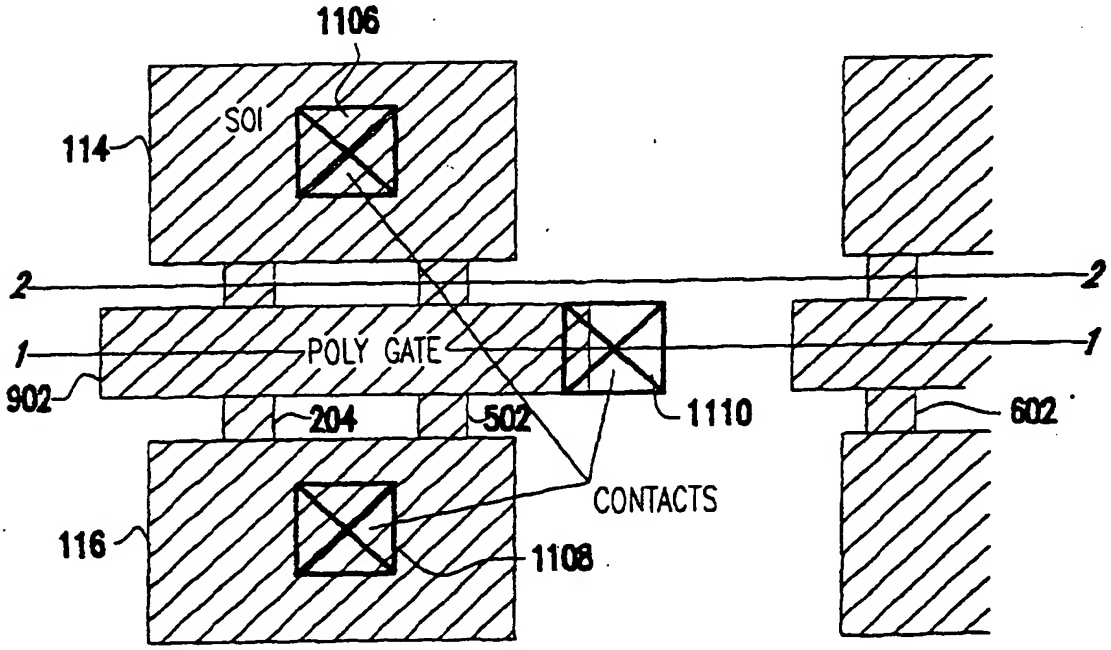

FIG.11B

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European Patent Office
Office européen des brevets

(11) EP 1 202 335 A3

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08.09.2004 Bulletin 2004/37

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(30) Priority: **18.10.2000 US 691353**

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Intellectual Property Department,
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(54) Method of fabricating semiconductor side wall fin

(57) A double gated silicon-on-insulator (SOI) MOSFET is fabricated by forming epitaxially grown channels, followed by a damascene gate. The double gated MOSFET features narrow channels, which increases current drive per layout width and provides low out conductance.

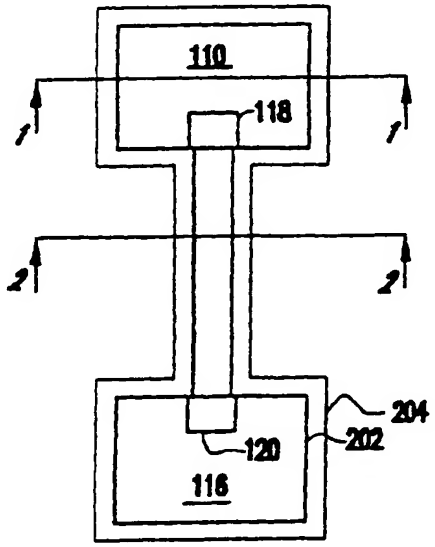

FIG.2A

EP 1 202 335 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 8767

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-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	16 July 2004	Hoffmann, N

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 8767

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Place of search	Date of completion of the search	Examiner
Berlin	16 July 2004	Hoffmann, N

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